

Treatment of Ground Water with Zero Valent Iron (ZVI)

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Presentation Summary

- What is ZVI?
- How does ZVI work?
- What contaminants are treatable with ZVI?
- How do we design for use of ZVI?
- What ground water chemistry changes occur in presence of ZVI?
- Application status of ZVI systems
- ZVI emplacement types and advances

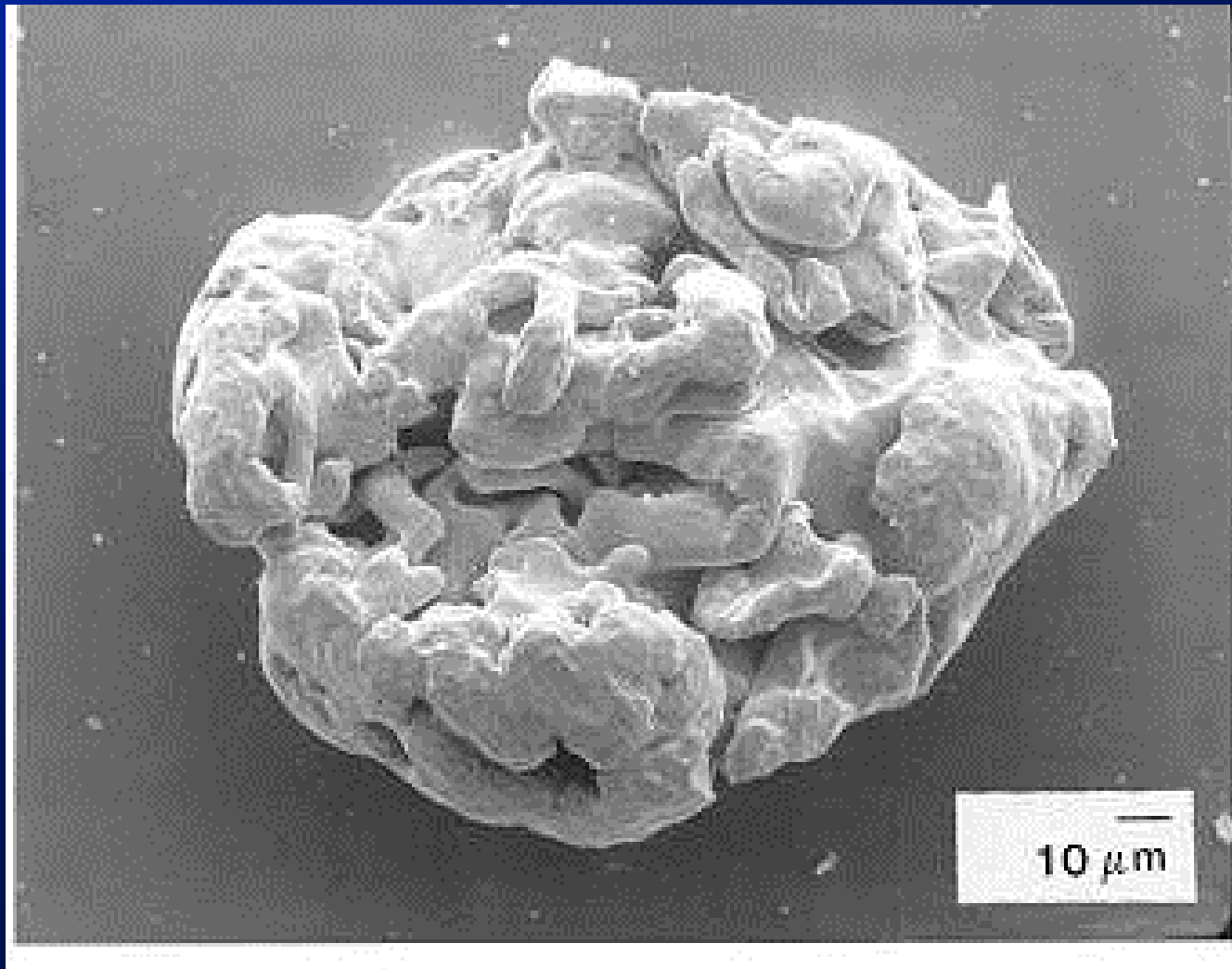
Zero Valent Iron (e.g. iron filings, powder)

Effective in treating ground water impacted by

- ◆ chlorinated ethenes
- ◆ chlorinated ethanes
- ◆ chlorinated methanes (some)
- ◆ dissolved metals



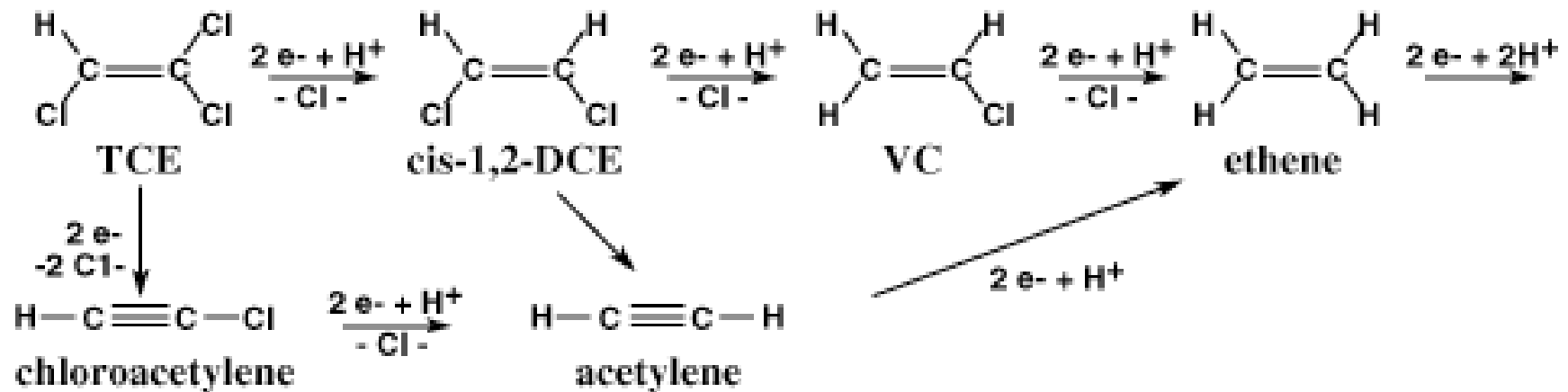
ZVI Powder



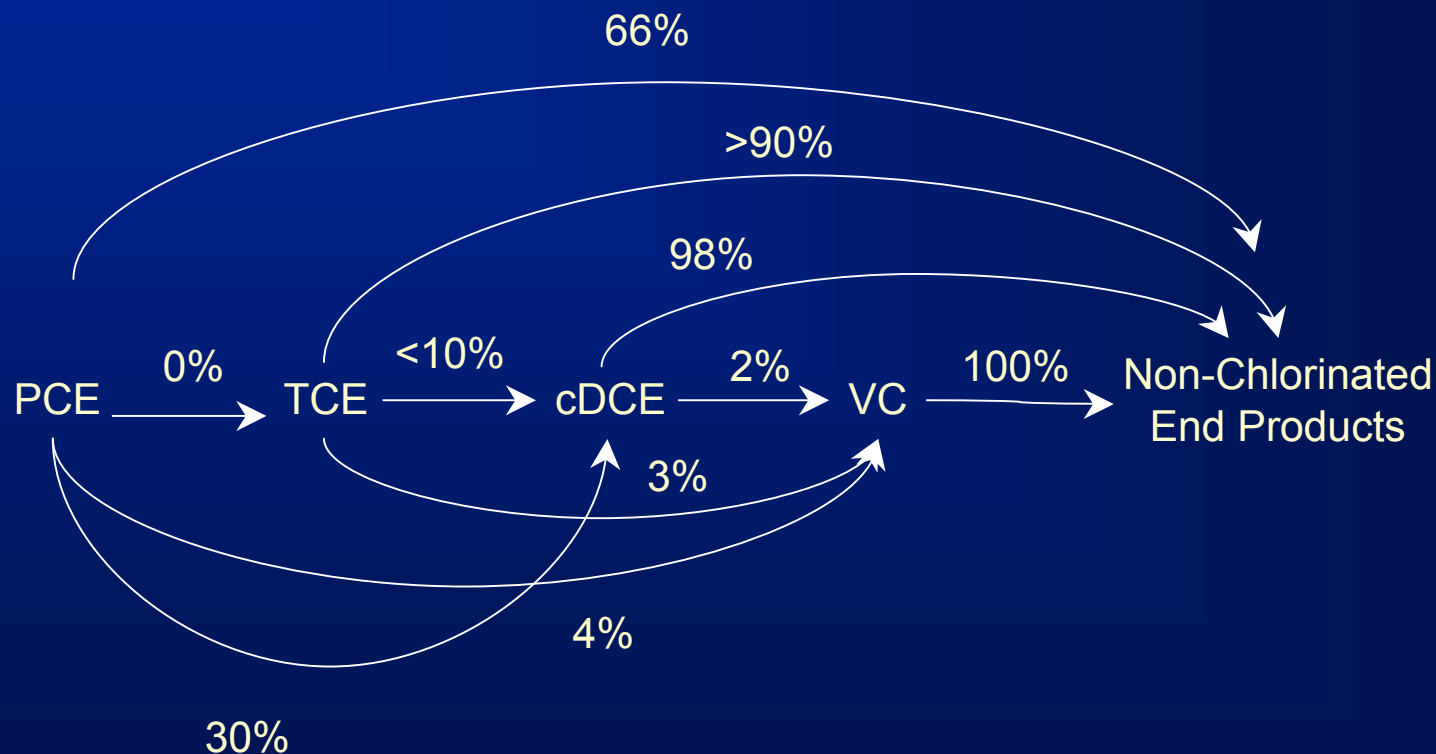
Reaction Mechanism

- Corrosion of iron drives reaction
- Iron provides electron source for reduction (dechlorination) of organics
- More highly chlorinated compounds degrade faster (TCE degrades faster than vinyl chloride)

Chemical Process - TCE



Observed Percent Conversions - Chlorinated Ethenes



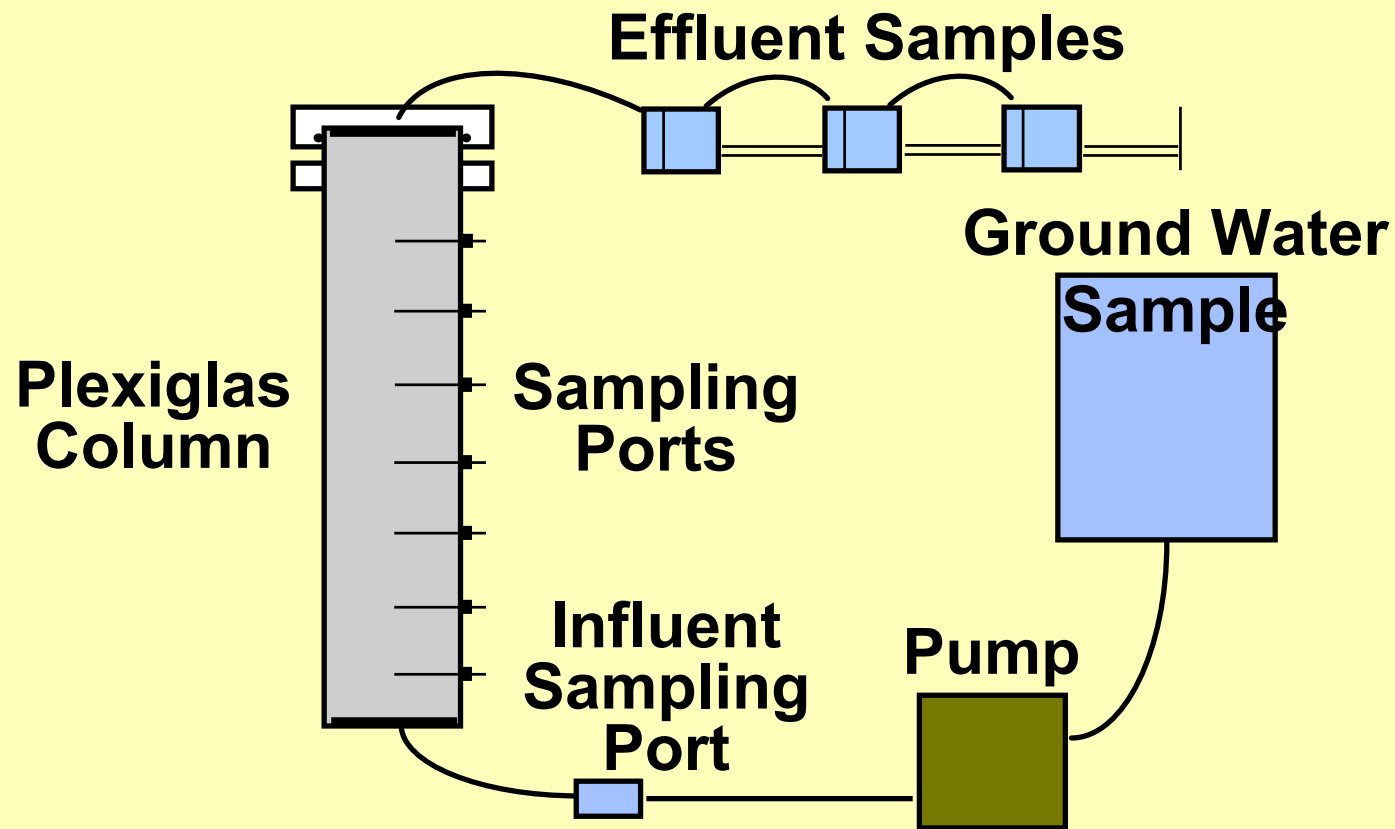
Contaminants Treatable by ZVI

Methanes	<ul style="list-style-type: none">• tetrachloromethane• trichloromethane	Propanes	<ul style="list-style-type: none">• 1,2,3-trichloropropane• 1,2-dichloropropane
Ethanes	<ul style="list-style-type: none">• hexachloroethane• 1,1,1-trichloroethane• 1,1,2-trichloroethane• 1,1-dichloroethane• 1,1,2,2-tetrachloroethane	Other	<ul style="list-style-type: none">• hexachlorobutadiene• 1,2-dibromoethane (EDB)• freon 113• freon 11• lindane• N-nitrosodimethylamine• Nitrobenzene
Ethenes	<ul style="list-style-type: none">• tetrachloroethene• trichloroethene• cis-1,2-dichloroethene• trans-1,2-dichloroethene• 1,1-dichloroethene• vinyl chloride		

Contaminant Half-Life Concept

- The half life of a contaminant is the time it takes for the concentration of the contaminant to reach one half of its original concentration.
- For example, if the original concentration of TCE is 100 mg/L (ppm) and the concentration after two hours in the presence of ZVI is 50 mg/L, then the half life of TCE is 2 hours.

Column Treatability Study Setup



Column Treatability Tests

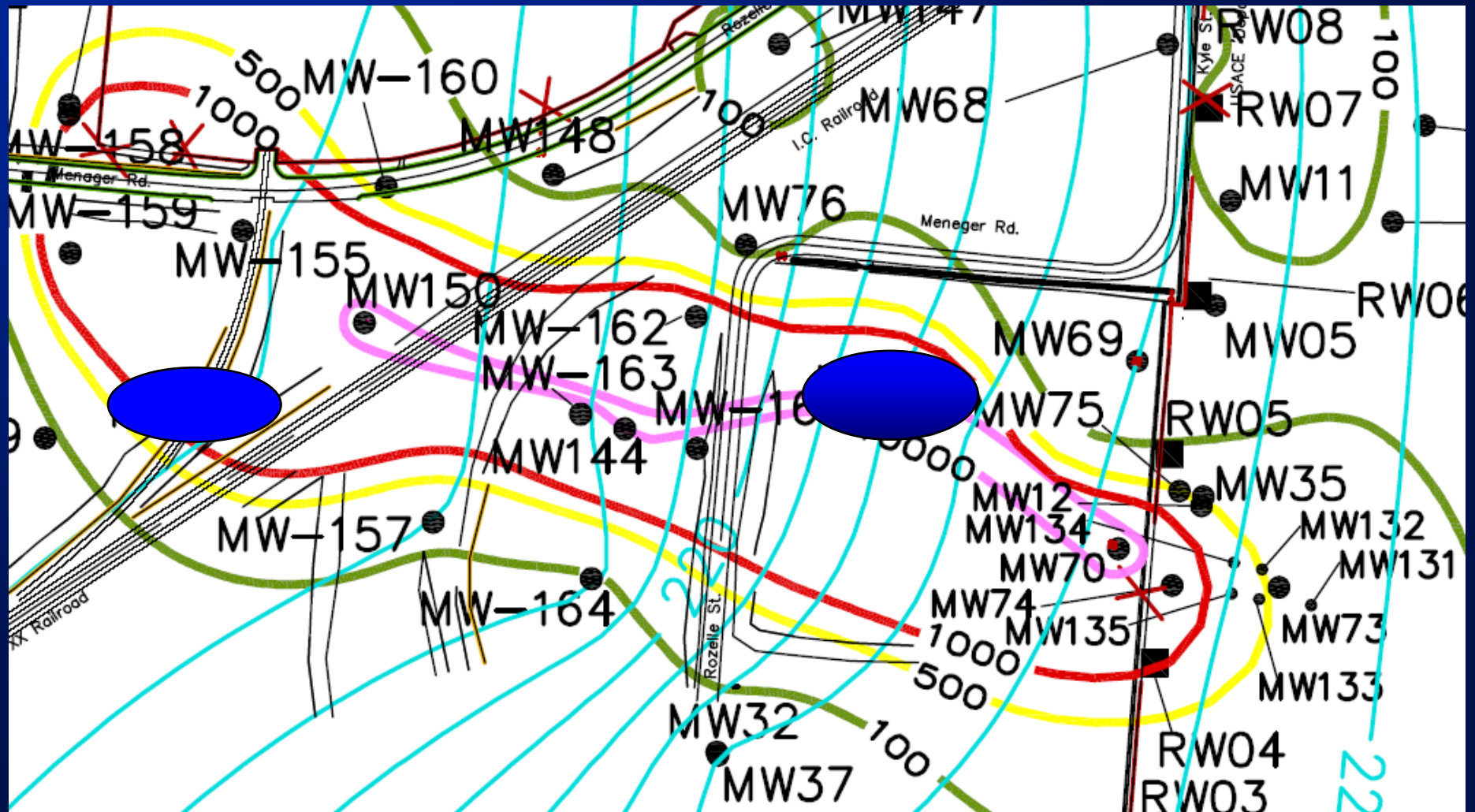
Yield site-specific half-life data for contaminants of concern

<i>Compound</i>	<i>Typical Half-Life (hours)</i>	<i>Compound</i>	<i>Typical Half-Life (hours)</i>
PCE	0.5-2	CT	0.5-1
TCE	0.5-2	TCM	1-3
<i>cis</i> 1,2-DCE	2-6	1,1,1-TCA	0.5-2
VC	2-6		

Dunn Field Column Test Half-Lives (hrs)

	<u>MW54</u>	<u>MW77</u>
CT	0.3	---
TCM	1.1	---
1,1,2,2-TeCA	1.5	1.3
1,1,2-TCA	---	2.5
PCE	---	2.9
TCE	2.0	2.7
Cis 1,2-DCE	2.4	4.1
VC	---	2.4

Well Locations MW54 and MW77



Half-life Discussion

- Assume column tests show TCE has a half life of 2 hours for treatment with ZVI
- If GW velocity is 1 foot per day
 - 12 inches / 24 hours (= 1 inch each 2 hours)
 - 2 hours of residence time per inch
 - (residence time is time spent in contact with ZVI)
 - 1 half life for each inch of iron thickness
 - 12 half lives requires 12 inches of iron

Half Lives (continued)

If

1 inch of travel time = 2 hours

&

1 half life = 2 hours

Then

1 inch of travel through ZVI = 1 half life of
treatment

Half-Lives (continued)

■ TCE (ppb)

- 10,000
- 5,000
- 2,500
- 625
- 160
- 40
- 10
- 2.5

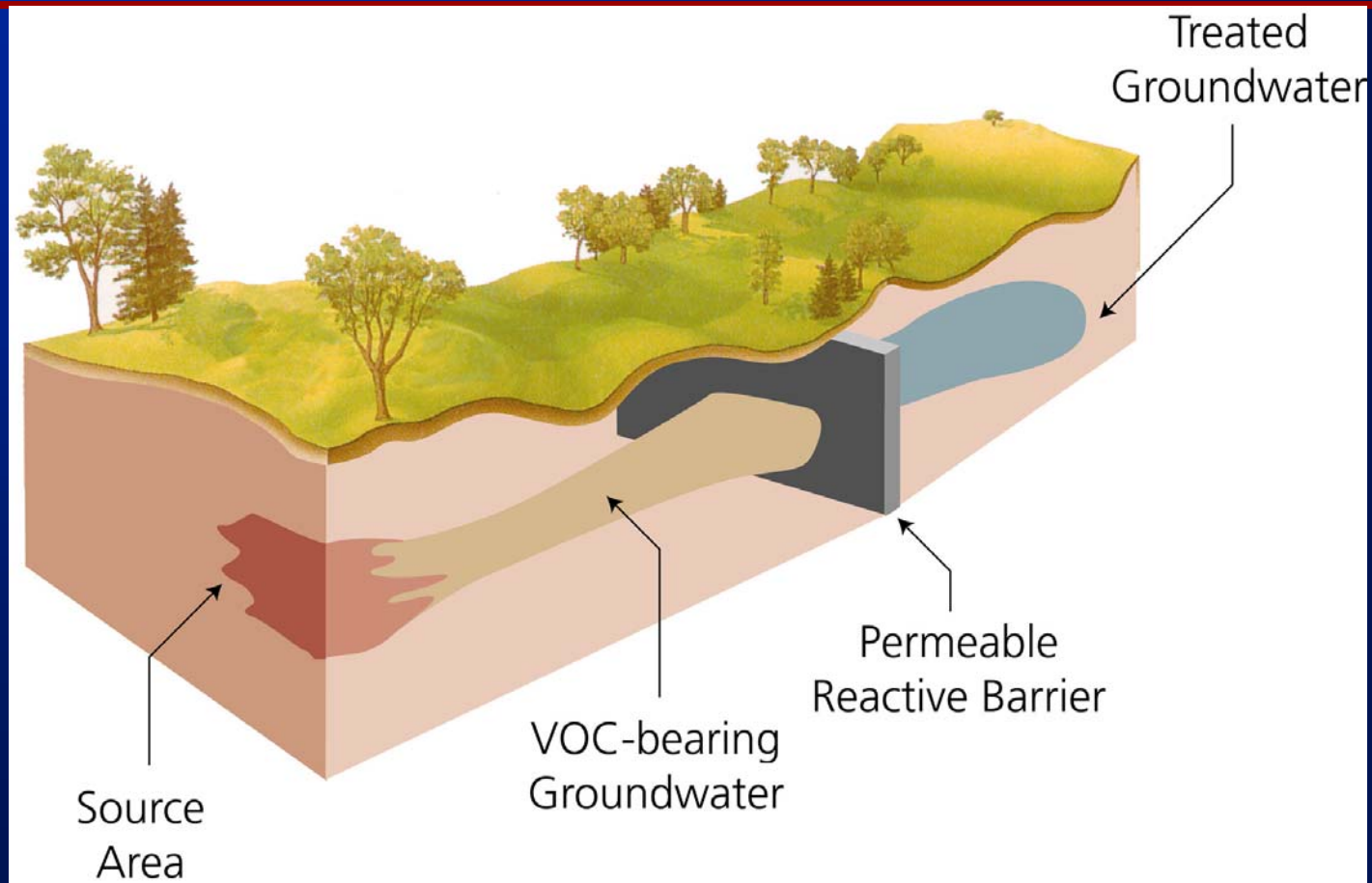
■ Half lives (residence time, ZVI thickness)

- 0
- 1 (2 hrs; 1 in thick)
- 2 (4 hrs; 2 in thick)
- 4 (8 hrs; 4 in thick)
- 6 (12 hrs; 6 in thick)
- 8 (16 hrs; 8 in thick)
- 10 (20 hrs; 10 in thick)
- 12 (24 hours; 12 in thick)

First ZVI Applications - Permeable Reactive Barriers (PRBs)

- **A permeable zone consisting of a reactive treatment area oriented to intercept and remediate a contaminant plume**
- **Removes contaminants from the ground water flow system by physical, chemical (ZVI), or biological processes**

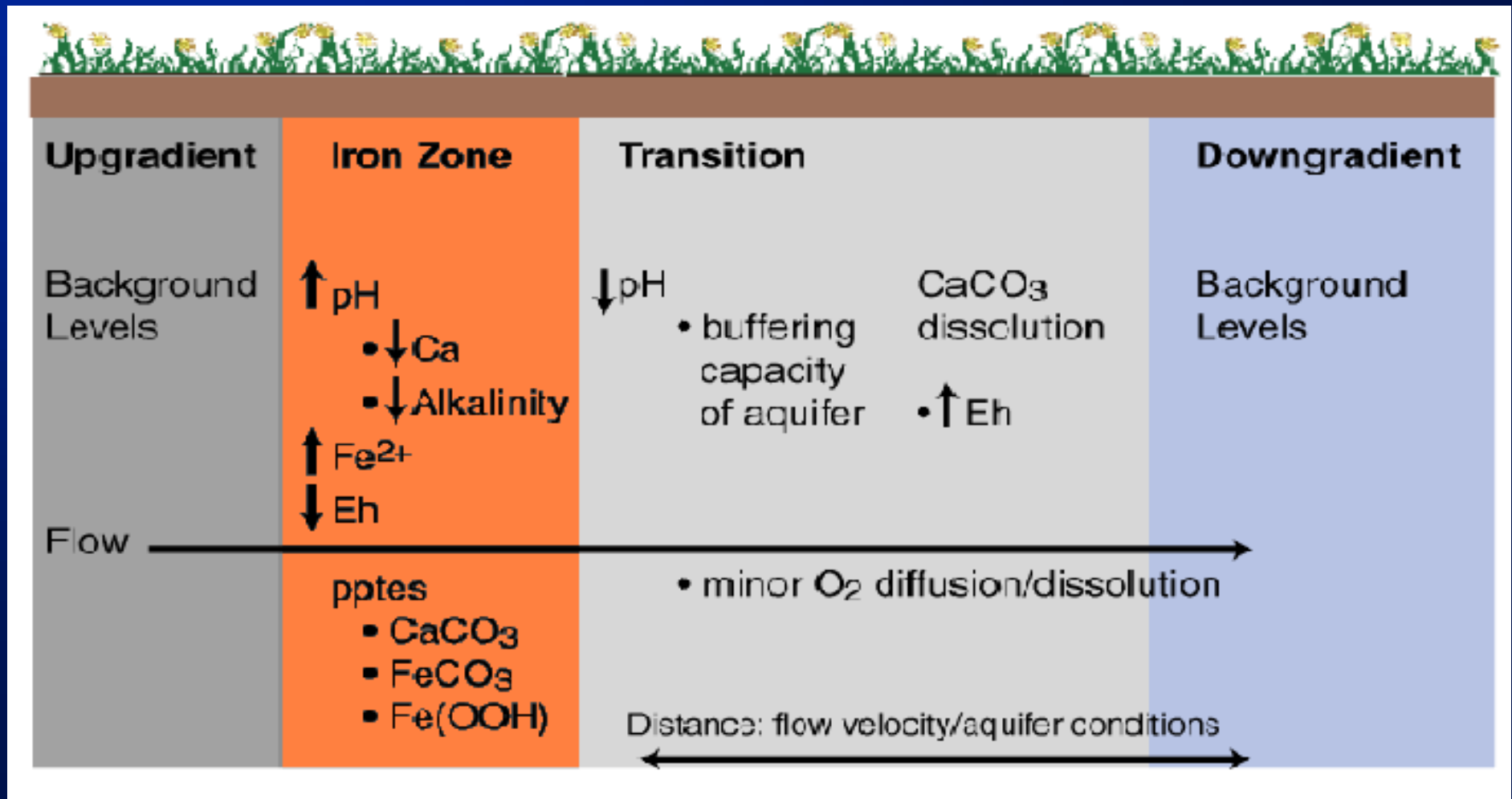
Conceptualization



ZVI PRB Systems

- **Effective in removing many chlorinated hydrocarbons**
- **Persistent over long time periods**
- **Low operating and maintenance costs**
- **No adverse geochemical reactions**

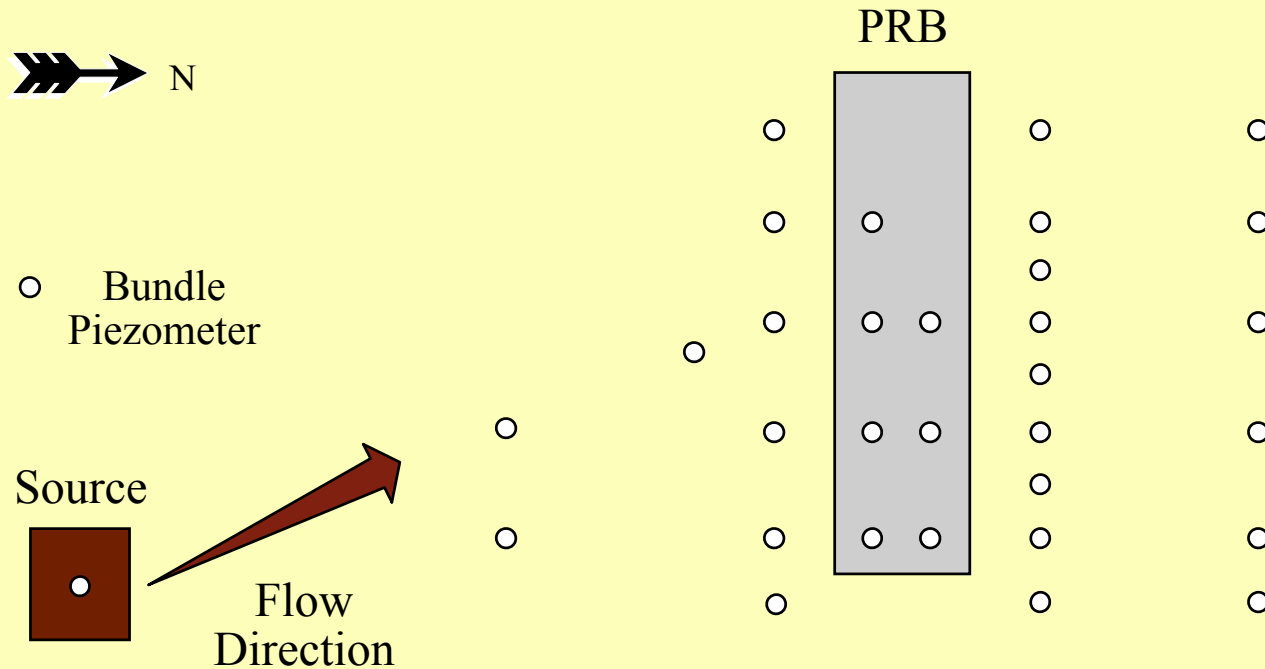
Ground Water Chemistry Changes



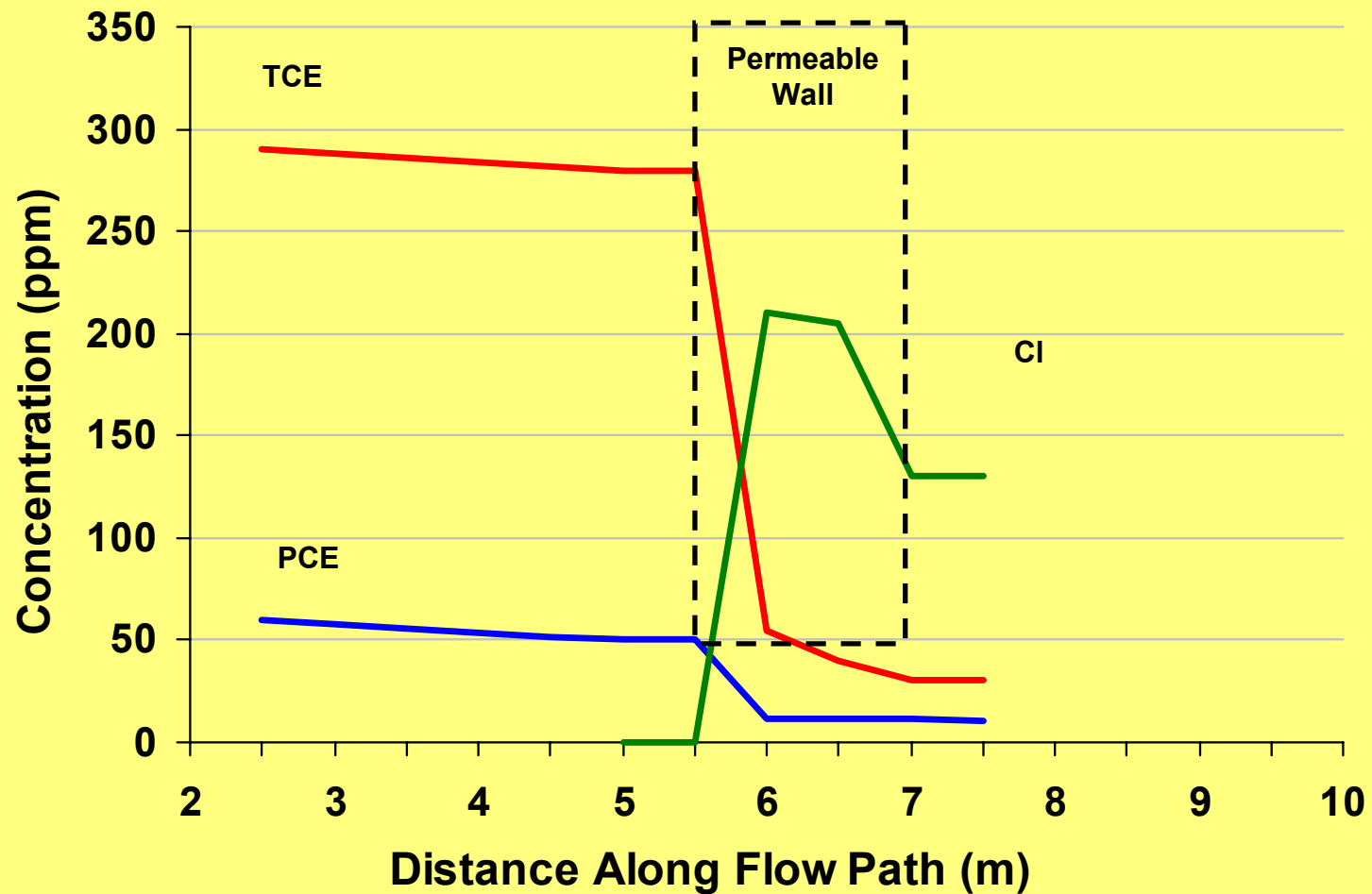
U. Of Waterloo Field Trial (1991)



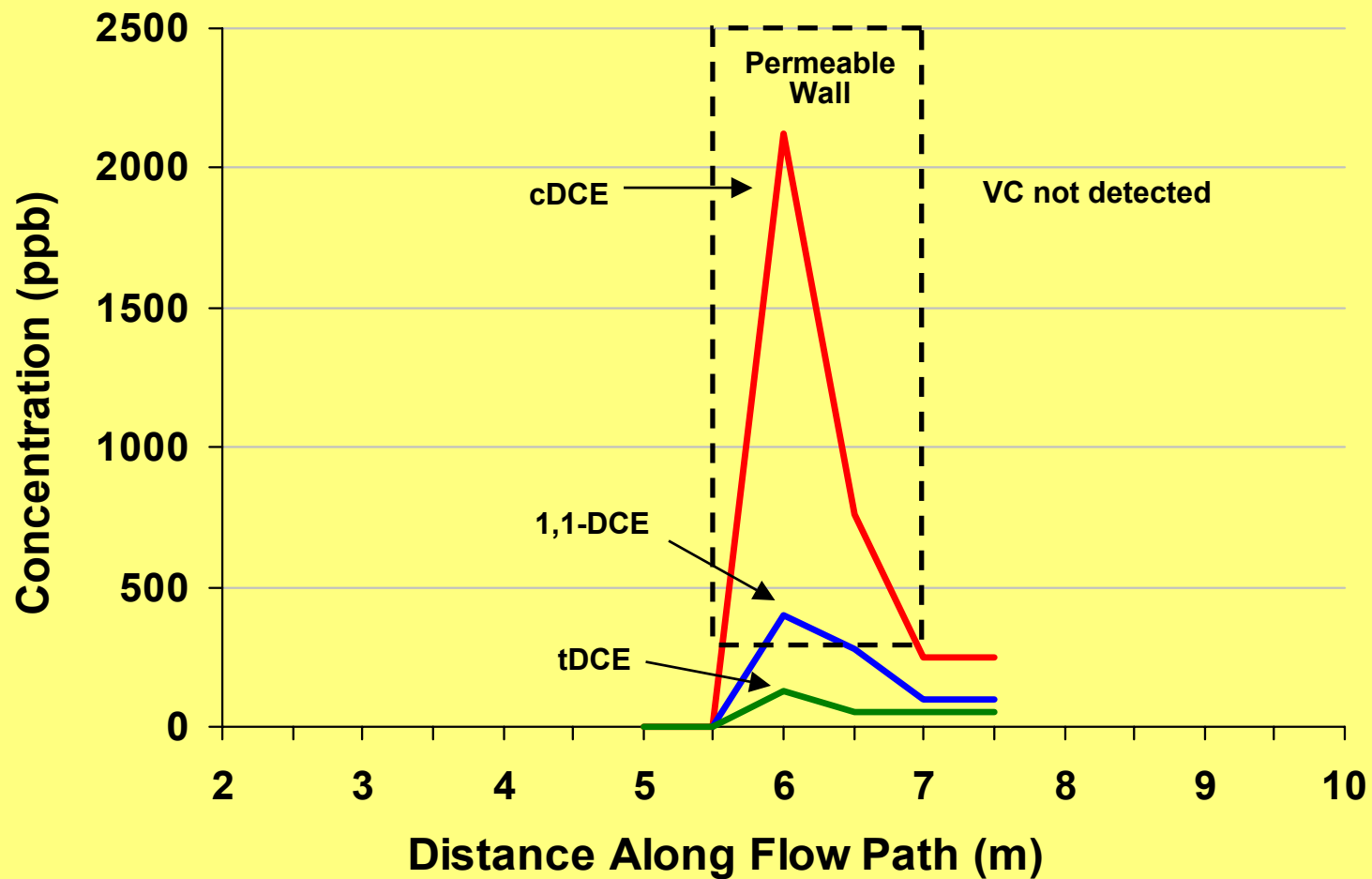
Waterloo Field Trial (1991)



Waterloo Field Trial (1991)



Waterloo Field Trial (1991)



First Commercial PRB Installation

Sunnyvale, CA (95)



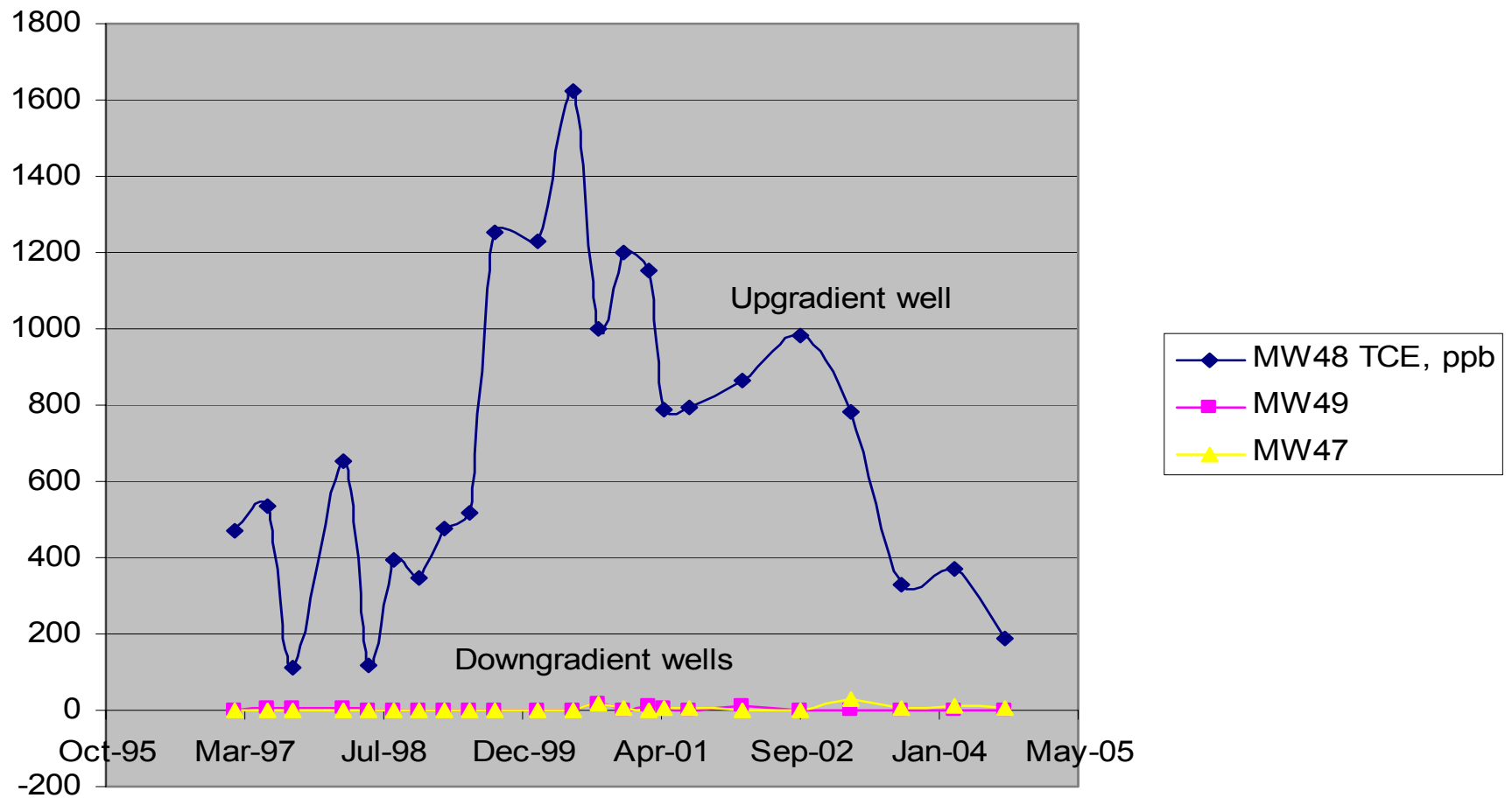
envirometal technologies inc.

Source: Geomatrix

Full-Scale Installation – Elizabeth City, N.C.



TCE in Compliance Wells – Elizabeth City



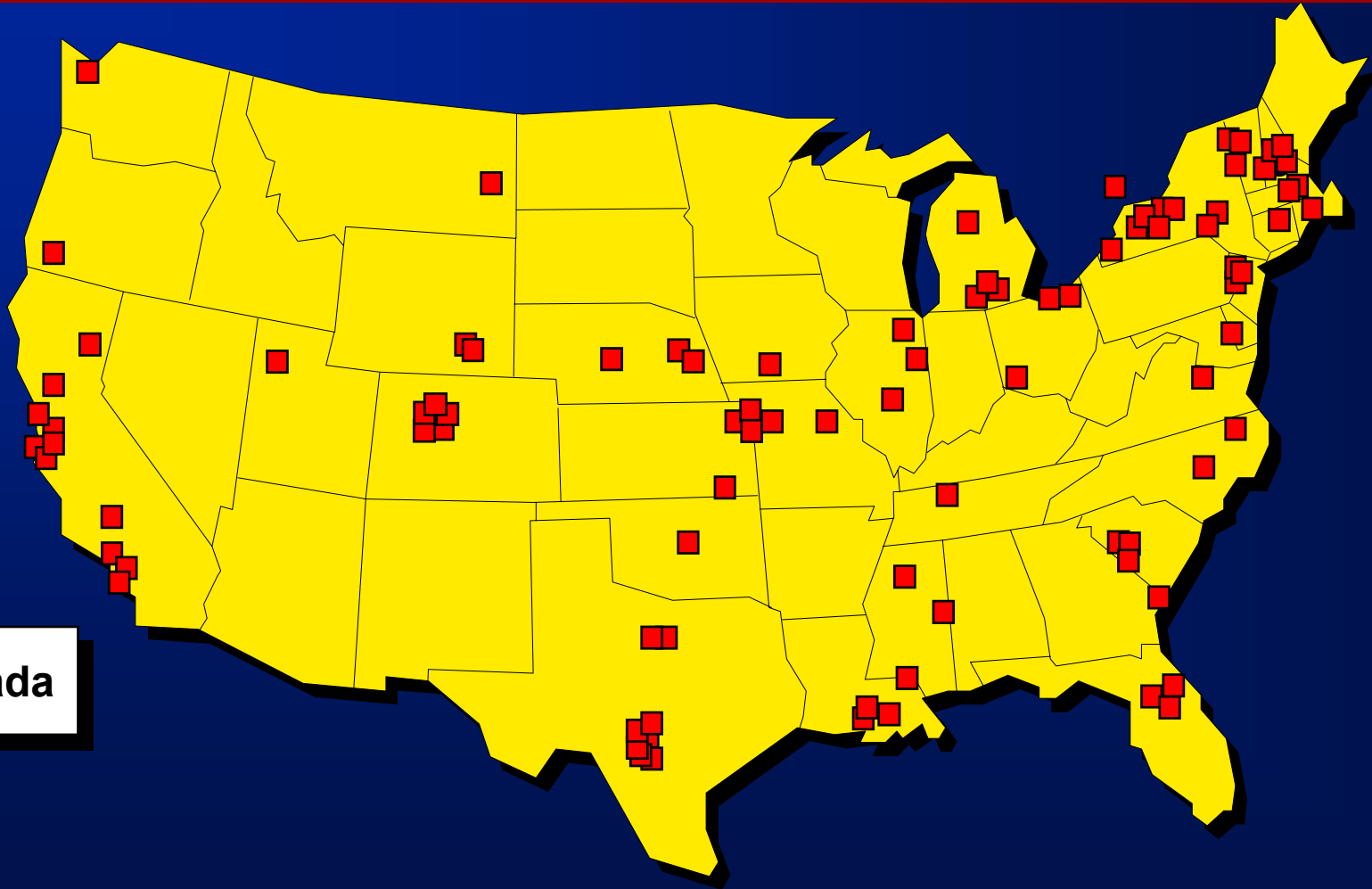
Status – ZVI PRB systems

1999 - 22 full-scale systems

- 14 private facilities
- 3 U.S. DOD facilities
- 2 U.S. DOE facilities
- 3 other government facilities

Currently – 83 full-scale systems world wide

91 USA Field Installations



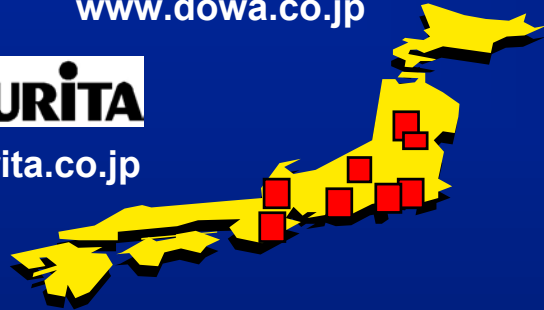
1 - Canada

25 Installations Around the Globe

Japan

DOWA
www.dowa.co.jp

KURITA
www.kurita.co.jp



Australia



1 - Australia
16 - Europe
8 - Japan

Europe

Netherlands

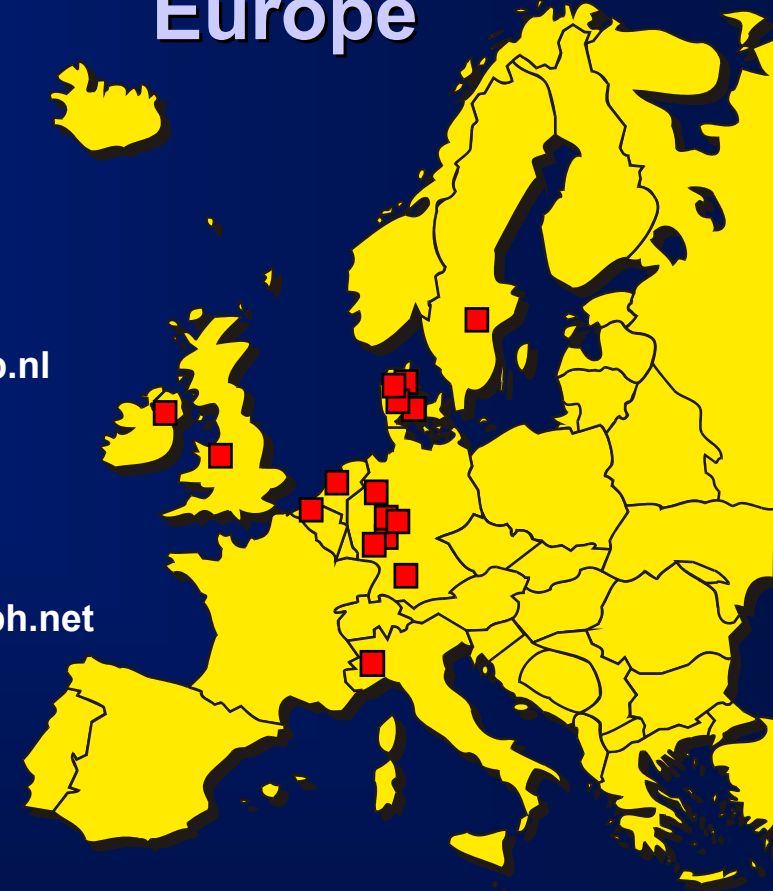


www.ntp-groep.nl

Germany & Italy

I.M.E.S.

www.imes-gmbh.net



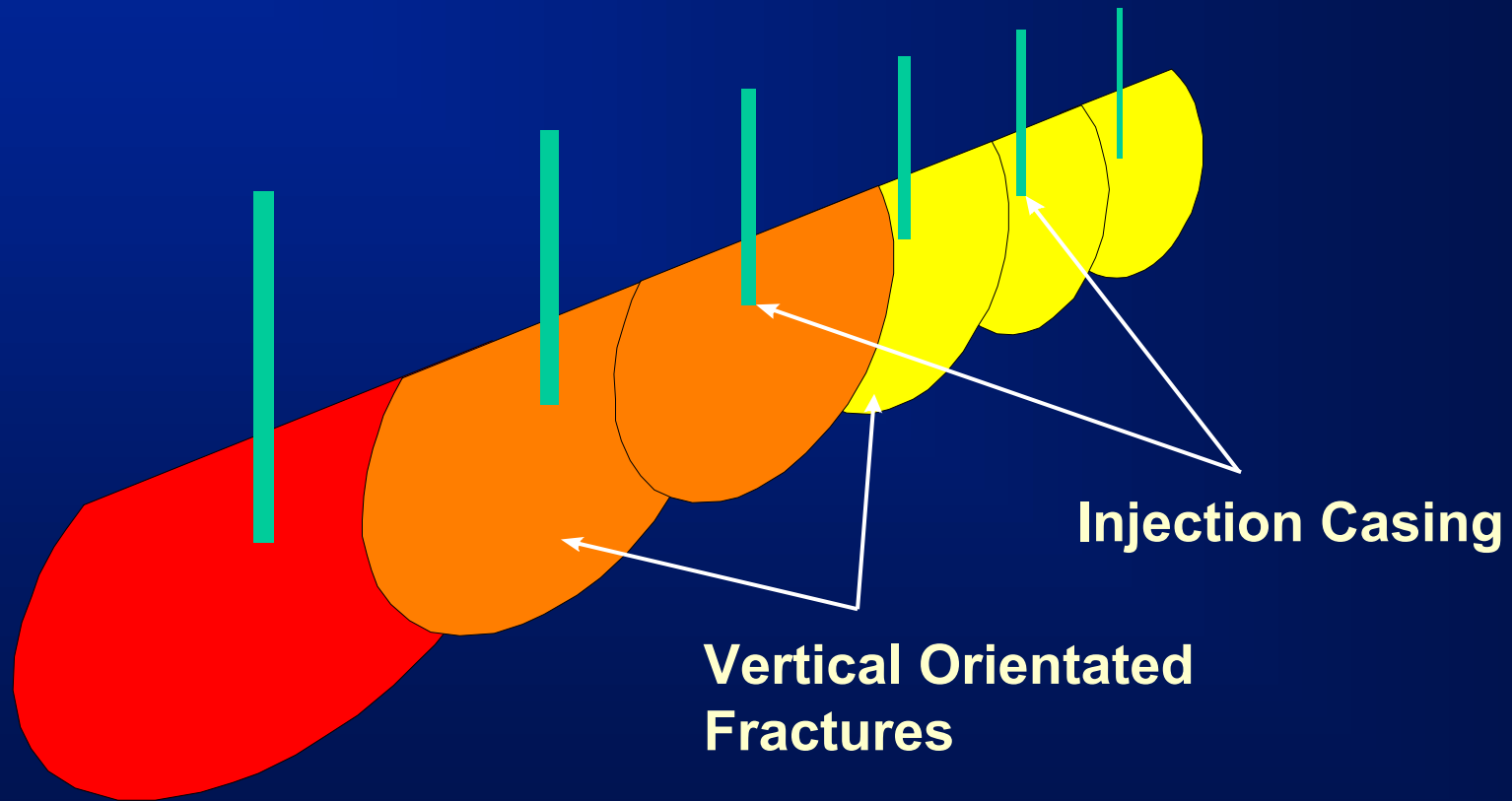
Emplacement Advances Summary

- ZVI can be placed to depths > 100 ft
- ZVI can be emplaced across selected depth intervals
- Recent advancements allow ZVI emplacement where trenching and excavation would be problematic

Vertical Hydraulic Fracturing

- Iron suspended in guar-based slurry
- Iron slurry injected at high pressure/low velocity
- Fractures propagate along vertical orientation
- Adjacent fractures coalesce to form continuous wall
- Slurry breaks down leaving permeable iron barrier

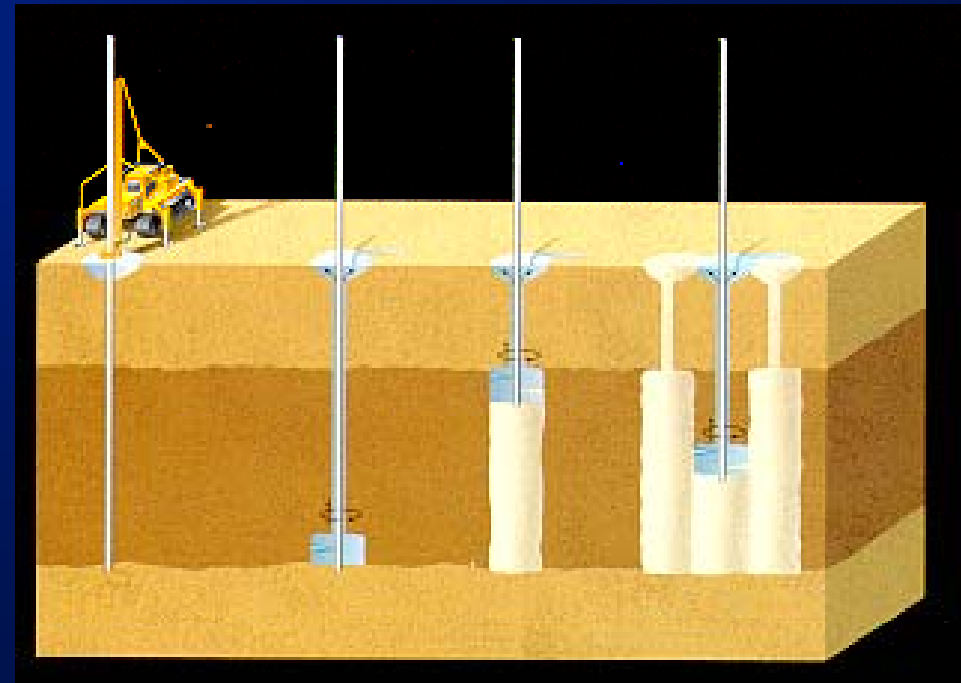
Overlapping Fractures



Panel Emplacement



High Pressure/High Velocity



High Pressure/High Velocity ZVI Injection

- Can be used to treat ground water hot spots
- Will result in contaminant mass reduction in ground water if effectively applied

Summary

- **ZVI is an effective treatment media for contaminants such as those found in ground water at the Dunn Field site**
- **Contaminants are permanently destroyed**
- **During reaction over time, ZVI is gradually transformed (oxidized) back to its original form in nature (i.e. back to iron oxide)**
- **ZVI does not adversely impact ground water**

Sources of Information

- www.rtdf.org
- www.eti.ca
- cgr.es.eogi.edu/iron
- www.itrcweb.org
- www.epa.gov/tio
- www.prb-net.org
- www.rubin-online.de